The Wi-Fi Evolution
An integral part of the wireless landscape
Wi-Fi: An integral part of the wireless landscape

Part of the solutions to “1000x mobile data challenge”

At the center of connected home

Opening new frontiers for wireless connectivity

Wi-Fi supported in all smart devices

The universal technology for smart connected homes

Leveraging ubiquity of indoor Wi-Fi for many new applications and services
Wi-Fi is becoming ubiquitous

Growing Global Reach

- 2011: 1.3M
- 2012: 2.1M
- 2013: 3.3M
- 2014: 4.5M
- 2015: 5.8M

Number of public hotspots worldwide. Source: Wireless Broadband Alliance (WBA) and Informa Telecoms & Media.

Expanding Device Support

<table>
<thead>
<tr>
<th>Wi-Fi Enabled Devices Shipped</th>
<th>2012 MU</th>
<th>2015 MU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phones/Accessories</td>
<td>685</td>
<td>1,459</td>
</tr>
<tr>
<td>Tablets, E-Readers, Media Players, etc.</td>
<td>199</td>
<td>360</td>
</tr>
<tr>
<td>Laptops, Desktops, Peripherals, etc.</td>
<td>392</td>
<td>717</td>
</tr>
<tr>
<td>Connected Home</td>
<td>107</td>
<td>287</td>
</tr>
<tr>
<td>Others</td>
<td>39</td>
<td>338</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,422</strong></td>
<td><strong>3,161</strong></td>
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A strong Wi-Fi evolution path

2.4 GHz/5 GHz

- 802.11 g
- 802.11 n

2012

2013

802.11ac
Breaking the Gbps Barrier

2014 and beyond

60 GHz

- 802.11ad
  Multi-Gigabit Short Range

Sub GHz (bands varies globally)

- 802.11 ah
  Sensor, Control

Higher capacity, higher data rates for mobile, computing, and CE devices

Wireless docking, in-room wireless display, audio, and more

Multi-year year battery life. Home/building automation, sensors and more
Qualcomm VIVE™: Enabling end-to-end 11ac ecosystem

Driving 11ac in migration in mobile through pin compatible solutions
Extending industry leading Wi-Fi performance¹
~6x lower power consumption (v/s our own 11n)

¹AnandTech - The HTC One X for AT&T Review by Brian Klug on 5/1/2012; "Unsurprisingly the One X posts the highest WLAN throughput I've seen from a smartphone to date."; This device uses Qualcomm's 802.11n solution
End-to-end portfolio maximizing 11ac benefits

**Mobile**
- 1-stream 11ac
- Integrated BT 4.0 & FM
- 433 Mbps capacity
- Dual-band 5/2.4GHz

**Computing**
- 1-, 2- and 3-stream 11ac
- Integrated Bluetooth
- 433, 866 Mbps & 1.3 Gbps
- Dual-band for all solutions

**Consumer electronics**
- 2-, 3-stream 11ac
- Integrated Bluetooth
- 866 Mbps & 1.3 Gbps
- Dual-band, dual-concurrent

**Networking**
- 2- and 3-stream 11ac
- 866 Mbps & 1.3 Gbps
- Integrated processor & switch
- Dual-band for all solutions

Smartphones & Tablets  Tablets, Notebooks, AIOs  Handsets, Gaming, eReaders, DTV, STBs, PNDs  Switches, Routers, Gateways, PLC, Femto
Wi-Fi: Part of the solutions to the “1000x Mobile Data Challenge”
Mobile data traffic growth—industry preparing for 1000x

Preparing for 1000x Data traffic growth

Global data traffic growth

~2x

From 2010-2011*

*Global growth, some regions grew more/less
Multiple efforts needed to address 1000x – Wi-Fi is an integral part of the solutions

Higher Efficiency across the system

- Next-Gen Wi-Fi with 3x more throughput (per stream)
- Wi-Fi/3G/4G Seamless interworking for selecting best access
- Wi-Fi to be integrated into virtually all 3G/4G small cells
802.11ac: Up to 3x increase in throughput per stream

3x more in the future with MU-MIMO

3x throughput now*

3x more aggregate throughput with MU-MIMO**

Higher data rates at all ranges

Lower latency

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** As compared to 802.11.n; **When compared to 3-stream 11ac SU-MIMO, considering only single stream mobile devices; 802.11ac standard supports up to 8-stream MIMO
802.11ac: Higher data rates at all ranges

Throughput (Mbps)

Distance from AP (m)

- **Up to 3x data rates (e.g. within same room)**
- **Consistently higher data rates (e.g. within home, office)**

Source – Qualcomm simulations; Assumptions - TCP/IP Throughput, Channel model D, 5GHz 11ac is 80MHz 3x3 3SS with ML and LDPC; 11n is 40MHz 3x3 3SS with ML and LDPC
MU-MIMO: Higher capacity with mix of devices

Simultaneously serving multiple devices by reusing resources

Simultaneously serves up to 3 devices

Up to 3x more aggregate throughput*

*When compared to 3-stream 11ac SU-MIMO, considering only single stream mobile devices
Tighter Wi-Fi—3G/4G interworking

Convergence of Cellular and Wi-Fi Infrastructure

Seamless Access and Connectivity

Combine Wi-Fi and 3G/4G
Passpoint™ – Seamless 3G/4G/Wi-Fi roaming

- Automatic discovery and access
  - No user intervention
  - Single set of credential for all hotspots
  - 3G/4G/ SIM/USIM based authentication

- Proven WPA2- Enterprise security

- Roaming among Wi-Fi and between 3G/4G Wi-Fi networks

- Deployments in 2013

Passpoint™ is known in standard as Hotspot 2.0
Multi-dimensional Wi-Fi—3G/4G interworking landscape

Many Wi-Fi deployment models

- Standalone
- 3G/4G Operator-Offered
- 3G/4G - connected (3rd party)
- Converged

Different levels of interworking

- Automatic discovery/access
- Service continuity
- Traffic selection (e.g., per app basis)
- Traffic combining and future enhancements

Device in unique position to select best access/es

Smart Connectivity Engine

Network Quality

Operator Policies
Seamless Wi-Fi—3G/4G interworking is evolving

- **Traffic selection**
  - E.g. - Best effort
  - E.g. - QoS
  - Per flow selection

- **Service continuity**
  - Combining data
  - Even tighter integration
  - 3GPP Rel 11 and beyond

**Notes:**
1) ANDSF - Access Network Discovery and Selection Function defined in 3GPP.
2) The evolution shown here represents the trend in commercialization. 3GPP supports Service continuity in Rel 8 and Traffic selection in Rel. 10
Qualcomm connectivity engine (CnE) – Selecting best access

Based on end-to-end link performance

3G/4G  Wi-Fi - 1  Wi-Fi - 2

Signal Quality  Available B/W  Internet Connectivity  Latency  Operator Policies

Standards compliant (Passpoint/Hotspot2.0, 3GPP (ANDSF), IWAN)

Smart algorithms (In addition to standards)

Part of Qualcomm chipset solutions
Qualcomm 3G/4G – Wi-Fi converged small cell Solutions

- Highly integrated SoC
  - 3G/4G, Wi-Fi (11n & 11ac)

- Complete reference designs
  - Modular, Flexible RF band support
  - RF Coexistence considerations fully addressed

- Intelligent end-to-end connection management
  - Hotspot 2.0/Passpoint support
  - Access selection based on information from both Wi-Fi and 3G/4G (QoS, resource constraints, loading, link quality etc)
  - Works even better with Qualcomm’s connectivity engine (CnE)

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<tr>
<th>Qualcomm’s Converged Small Cell</th>
<th>Standard Converged Small Cell</th>
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<td><strong>Device with CnE</strong></td>
<td><strong>Most optimized selection with end-to-end information</strong></td>
</tr>
<tr>
<td><strong>Device w/o CnE</strong></td>
<td><strong>Intelligent selection based only on AP info</strong></td>
</tr>
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Wi-Fi: At the center of “Smart Connected Homes”
Connected home vision: Multiple smarts working together

Manage devices/apps to maximize efficiency, and provide homogenized user experience (e.g. smart bandwidth management based on app requirements)

Deliver a personalized connected home experience (e.g. smart TV, smart appliances)

Extend resources of the home network when needed, by providing additional data, storage space and computing capabilities
Wi-Fi: Universal technology in “Connected Homes”

- **Hy-Fi™**
  - PLC (Home Plug AV)
  - Others

**CLOUD**

**Smart Gateway**

- Wired or 3G/4G

**Multimedia**

**Home Operations**

**Life Management**

**Bring Your Own Device (BYOD)**

PLC – Power Line Communications
Home Plug AV – Standard for Audio/Video over PLC
StreamBoost™: Taking 11ac to the next level

Intelligent traffic management for best possible performance

- Allocates appropriate bandwidth to each app/device for the best experience
- Makes the most of the finite available bandwidth
- Cloud-based updates continue to optimize network performance
- Supported in all ViVE networking chipsets
Qualcomm Hy-Fi™: Combining Wi-Fi, PLC and Ethernet

Mobility and flexibility of Wi-Fi with reliability and range of PLC
Wi-Fi: Opening new frontiers
Wi-Fi: Foundation for all wireless display technologies

Wi-Fi display solutions
(e.g. AllJoyn™ based media shifting apps, Skifta, and others)

- Mandatorily uses Wi-Fi Direct
- Captures contents of source display and renders on the target
  - Mirrors the entire display, not just "transferring" media

All wireless display solutions use Wi-Fi
WiGig: Short-distance multi-gigabit connectivity

Leveraging bandwidth-rich 60 GHz spectrum with 802.11ad

- **Globally Harmonized Band**
  (Up to 9 GHz available in most countries)

- **Complements 11ac**
  (for short distance/same-room communication)

- **Strong Industry Support**
  (Major players from PC, Mobile & CE segments)

- **Instantaneous Docking/Synching**
  (Peer-to-peer)

- **Internet Access**
  (complementing 11ac)

- **High-Performance Wireless Display/Audio**
  (Uncompressed transfer, Peer-to-peer)
Industry’s first tri-band WiGig solution

- Tri-band - 2.4, 5 and 60 GHz
- 10x more in-room performance*
- Seamless transition with 11n & 11ac
- Commercial now (PC/Docking Station)

Dell Latitude 6430u, world’s first WiGig device – built on Qualcomm Tri-band solution

Combining Qualcomm’s VIVE™ 11ac solutions with Wilocity’s 802.11ad
Precise indoor positioning – Using Wi-Fi, sensors and more

Wi-Fi network based determination
- Signal strength and delay measurements
- Accuracy 5-7 mts

Device-based determination
- Signal strength and delay measurements
- Sensor augmentation
- Accuracy 3-5 mts

End-to-end solution provides highest accuracy and reliability
Qualcomm IZat™ – Precise positioning everywhere

Comprehensive end-to-end solutions

1st to market with GPS + Glonass

Indoor Location Solutions
(including cloud based data bases & services)

Satellite-Based GNSS Solutions

Augmentation Technologies
(Cellular, Wi-Fi, Sensors, Servers)

Always-ON indoor location with near-zero power consumption

Integrated into all MSM, MDM and APQ platforms
(and discrete solutions)
Qualcomm: Wi-Fi evolution leadership

Enabling robust end-to-end 11ac Ecosystem

Comprehensive connected-home solutions

Trendsetting in-door positioning & WiGig offerings

Industry leading solutions with end-to-end excellence
Questions? - Connect with Us

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